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TITLE

Female vs male shivering EMG responses to 10C air

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FEMALE VS MALE SHIVERING EMG RESPONSES TO 10°C AIR

Peter Tikuisis, Ira Jacobs, Diane Moroz, Andrew Vallerand and Doug Bell

Defence and Civil Institute of Environmental Medicine
Toronto, Ontario, Canada M3M 3B9

INTRODUCTION

This was the second of two studies undertaken to compare the thermoregulatory responses to cold between females and males. Previously, we found that gender-related corrections to prediction models of thermoregulation in the cold are not required provided that the models take body fatness into account. In the present study, we compare the shivering characteristics between females and males exposed to a less stressful cold condition. Specifically, the onset of shivering and the contribution of various muscle groups to overall shivering heat production are examined.

MATERIALS AND METHODS

Fifteen young and fit females (see Table 1 below; body fat was estimated *via* body density by hydrostatic weighing) participated in this study. The experimental procedure used is detailed in Bell et al. [1] and Tikuisis et al. [2]. Data from the previous cited study on ten males (also tabled below) were used to compare the results of the present study. Subjects abstained from alcohol for 48 h and fasted for 12 h before the trial, and did not exercise within 24 h of the trial. Following instrumentation and baseline measurements of metabolic rate and muscle electromyographic activity, the subjects were exposed to 10°C air and 40% relative humidity for 2 h in a supine position. All values reported are mean ± SD.

Table 1. Subject characteristics (mean ± SD): all values between genders are significantly different.

Gender	n	Age (yr)	Mass (kg)	Ht (cm)	SA (m^2)	BF (%)
male	10	35.1 ± 4.0	77.3 ± 10.4	179 ± 6	1.97 ± 0.14	12.6 ± 5.4
female	15	28.0 ± 6.3	63.9 ± 8.7	163 ± 5	1.76 ± 0.12	23.2 ± 4.8

Rectal (using a rectal probe located 15 cm past the anal sphincter) and skin temperatures (12-point system), and heat flux were measured continuously and averaged each minute. The metabolic rate (M) was determined from the respiratory gas exchange measurements of oxygen consumption and carbon dioxide production rates measured continuously throughout the exposure with the exception of 10 min breaks every half hour.

Electromyographic (EMG) electrodes were placed on six muscle sites representing the trunk and limbs: pectoralis major (PE), rectus abdominis (AB), biceps brachii (BB), brachioradialis (BR), rectus femoris (FE), and gastrocnemius (GA). Subjects performed a series of voluntary isometric contractions with each muscle so that a regression of EMG against force could be established for each subject. After performing a maximal voluntary contraction (MVC), subjects were then asked to do three contractions at 50, 20, and 10% and 5% of the highest MVC. During the 2 h cold air exposure, the integrated EMG was averaged over each minute, but the 3 min intervals around the break (every 15 min) were not included in the analysis. Resting EMG was subtracted from EMG to provide only the shivering component denoted as EMG_{shiv}. The relative shivering intensity was obtained by dividing EMG_{shiv} by the EMG_{MVC} (also with the resting component removed) for the muscle. A whole body index of shivering intensity (SUM, expressed as a

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$$SUM = 100 \sum m_i \, (EMG_{shiv} / EMG_{MVC})_i \qquad (1)$$

Muscle mass factors used (see Ref. [1]) were 0.34 for PE (upper trunk), 0.19 for AB (lower trunk), 0.06 for BB (upper arm), 0.035 for BR (lower arms), 0.29 for FE (upper legs), and 0.085 for GA (lower legs). Finally, a specific muscle's contribution to overall body shivering (%Contribution) was determined by dividing the relative shivering intensity of that muscle by SUM. Significant differences were determined using a paired t-test at $p < 0.05$.

$$\%Contribution_i = m_i \, (EMG_{shiv} / EMG_{MVC})_i / SUM \qquad (2)$$

Shivering onset was characterized by the half-time ($t_{1/2}$) of the shivering response

$$EMG_{shiv} = EMG_{ss} \cdot [1 - \exp(-0.693 \, t/t_{1/2})] \qquad (3)$$

where EMG_{ss} represents the steady state shivering level (assumed equal to the mean EMG_{shiv} over the last 15 min of the 2 h exposure). The above equation was first regressed against the male data (mean of 1-min values) for each muscle separately. This regression was then repeated for the female data using the male-fitted values of $t_{1/2}$ as the initial estimate of the half-time. The F-ratio test at $p < 0.05$ was used to determine whether the regressed fit of $t_{1/2}$ was significantly different between genders.

RESULTS

There were no gender differences in T_{re}, the metabolic response to the cold (normalized by body surface area), or the resultant heat debt (129 ± 32 and 125 ± 32 $W \cdot h \cdot m^{-2}$ for females and males, respectively). There was, however, a significant transient rise in T_{re} in both genders during the first 45 min of exposure and a slow decrease thereafter. However, the mean T_{re} after 2 h of exposure (37.00 ± 0.30°C) was still significantly greater than the pre-exposure value (36.86 ± 0.19°C). MR increased in both genders for the first 90 min of exposure and then leveled off (consecutive 30 min values were 59.4 ± 12.6, 65.1 ± 11.6, 76.8 ± 16.4, and 77.8 ± 14.8 $W \cdot m^{-2}$). SUM also increased significantly and similarily to MR (corresponding 30 min values were 3.49 ± 2.54, 4.88 ± 2.84, 6.37 ± 4.04, and 6.17 ± 3.63%). Figure 1 illustrates the relationship between SUM and the shivering component of MR (expressed per kg of lean body mass) for the females. The positive correlation establishes the validity of the sites chosen to represent regional shivering activity.

Figure 2 shows the half-times of shivering onset. Males exhibited a lower $t_{1/2}$ (indicating a faster rise to steady state) than females in FE (23.4 ± 4.2 *vs* 45 ± 7.7 min) and AB (5.1 ± 1.3 *vs* 14.0 ± 2.0), but a higher value in PE (19.8 ± 1.6 *vs* 10.9 ± 1.5), BB (48.0 ± 5.8 *vs* 30.9 ± 3.5), and BR (67.9 ± 15.4 *vs* 35.4 ± 4.8). There was no significant gender difference in the shivering onset of GA.

In females, there was no significant difference in the contribution to SUM between PE (48 ± 28%) and AB (36 ± 27%), however, each of these muscles contributed significantly more to SUM than any of the peripheral muscles. There was no significant change over time of exposure in the %Contribution of a given muscle to SUM.

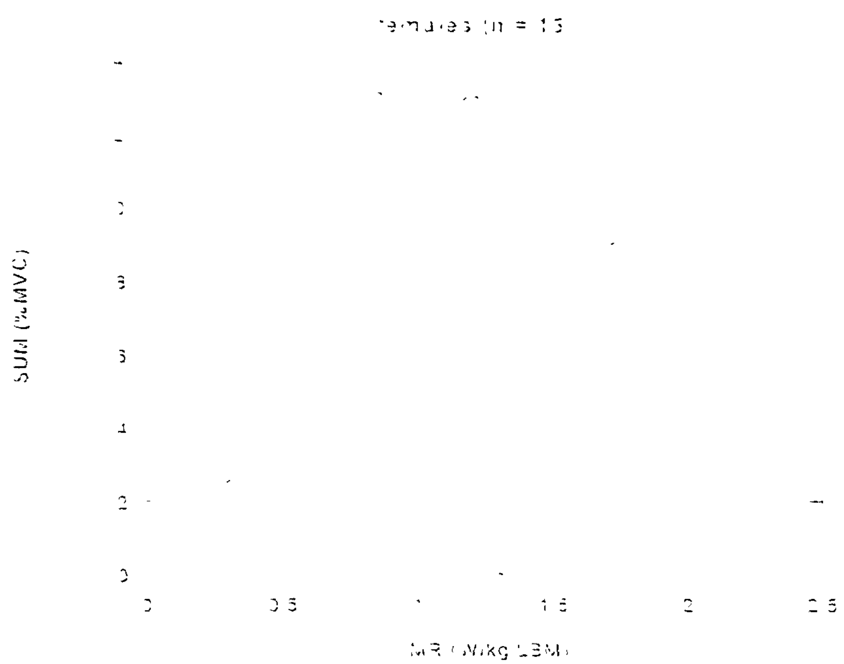

Figure 1 Correlation between whole body index of shivering and metabolic heat production due to shivering in females during the 2 h exposure to 10°C air. Each point represents the mean value of a specific subject.

To compare the contributions of different body regions to shivering between genders, data were grouped according to region. The legs (FE + GA) contributed more to shivering in males than females (26.0 ± 2.2 vs 8.8 ± 1.5%). The opposite occurred in the trunk muscles (PE + AB) which contributed more in females than males (84.5 ± 1.8 vs 70.7 ± 2.2%). The contribution of the arm muscles (BB + BR) were not different between the females (6.9 ± 0.7) and males (3.2 ± 0.3).

DISCUSSION

Males exhibited higher contributions from the leg muscles than females whereas the opposite occurred in the trunk region. It is uncertain how these differences might have affected the observed body heat loss. Theoretically at least, the legs are more susceptible to heat loss than the trunk due to a higher surface area to volume ratio. Hence, increased heat production in the legs is not efficient in terms of heat debt management. Yet, the data did not indicate gender differences in overall body heat loss. It is possible that differences in fat distribution between males and females had a canceling effect. That is, relatively higher subcutaneous fat levels in the male abdominal region and in the female thigh region provide greater insulation to these respective regions of relatively lower heat production so that the overall heat production was more evenly retained. Although shivering onset rates were different in most muscles between genders, the impact on heat balance was probably insignificant. This is because most of the shivering heat production occurred in the trunk and the opposing onset rates between genders for the AB and PE muscles would also have had a canceling effect.

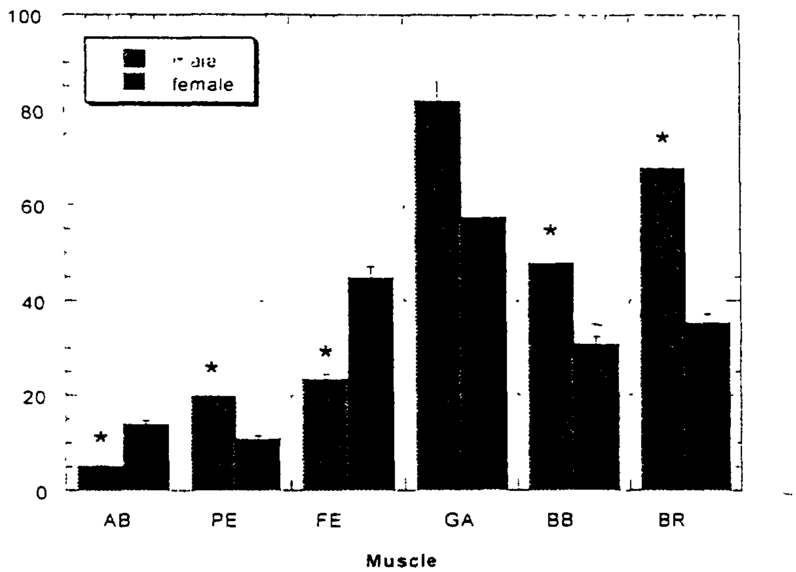

Figure 2 Mean (± SD) half-times of shivering onset for each muscle group in males and females exposed to 10°C air for 2 h (* indicates a significant gender difference)

CONCLUSION

Although gender differences in the regional onset of shivering and contribution to overall heat production were found in this study, these differences did not cause differences in the changes in deep body temperature or heat debt. It was speculated that this was due, in part, to cancellation effects of regional differences in fat distribution and shivering activity Perhaps under more challenging cold conditions, differences in shivering characteristics might lead to significant differences in thermal strain It would be prudent, therefore, to incorporate regional values of shivering onset and heat contribution in models of thermoregulation for completeness.

ACKNOWLEDGEMENT

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